Semi-Annual Technical Report PTR-1061-78-6 (I)
Contract No. MDA903-78-C-0127
ARPA Order No. 3488
Period Covering December 1, 1977 to May 31, 1978
Report Date June 1978

AUTOMATED COMPUTER SUPPORT OF C3 FUNCTIONS IN SMALL TACTICAL UNITS:

PART I - ADAPTIVE INFORMATION SELECTION

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NOTES

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Command control and communication

This report covers the first six months of a one-year research and development program directed towards the design and incorporation of an Adaptive Information Selection scheme used within a C3 environment with special emphasis on the Tactical Combat Operations(TCO) system. A multi-attribute evaluation model is used to determine the proper dissemination of TCO messages. The development of an in-house simulation using the existing Tactical and Negotiations Game is discussed. A background cont >

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rationale is given to present the need for such an aid. The MTACCS Interim Test Facility within which the Adaptive Information Selector will eventually be implemented, is discussed in detail. An analysis was performed to determine the attributes available from the messages and message headers resident in the MTACCS Interim Test Facility Database. A training scheme is developed tailored to the actual operator actions performed during exercises at the Test Facility. The principal functions making up the AIS are defined and their interfaces shown in a functional information flow diagram. The database management system used at the MTACCS Interim Test Facility is discussed including the definition of some of its data structures. Finally, an estimated burden of the AIS as it will be implemented on the MTACCS Interim Test Facility is presented.

ABSTRACT

TABLE OF CONTENTS

1. SUMMARY

1.1 Objectives

This report covers the first portion of a one-year program of research, development, and software design. The program is directed toward (a) the development of a general purpose methodology of adaptive information selection (AIS) for C3 systems; (b) the development of software and procedures for AIS implementation in specific C3 sytems, e.g., the Marine's Tactical Combat Operations (TCO) system. Specific objectives of the program included:

(1) An analysis of TCO operations and identification of the specific functions to be performed by the AIS.

(2) Development of the overall structure of the AIS model, specification of principal functions, formulations of data structures, and definition of model attributes accessible from the simulated TCO messages resident in the data base of the Marine Tactical Command and Control System (MTACCS) Interim Test Facility.

(3) A preliminary estimate of the operating burden of the AIS.

(4) A review and analysis of the evaluation measures planned by the Marine Corps Tactical Systems Support Activity (MCTSSA) for the coming MTACCS Interim Test Facility exercises in the light of AIS evaluation procedures.

These objectives were met by reconciling and integrating the Adaptive Information Selection Concept within the framework provided by TCO and Interim Facility-related documents. In particular, the present adaptive

multi-attribute evaluation model utilizes a trainable utility (evaluation) estimator previously developed for computer aiding of dynamic decision processes. This estimator has been modified to train in a simulated TCO environment on the Marine's Interim Test Facility.

The program is being conducted with the continuing close cooperation and support of the Marine Corps Tactical Systems Support Activity (MCTSSA), Marine Corps Base, Camp Pendleton, California. MCTSSA will provide battalion test scenarios, access to their Interim Test Facility, and Marine evaluation personnel. Selected support functions will be developed and evaluated within the framework of the Tactical Combat Operations (TCO) system.

1.2 Technical Approach

1.2.1 Support Requirements. Modern tactical warfare presents a complex and dynamic environment, involving computerized weapons systems, fast ground and air vehicles, and, most important, a surplus of incoming information. The battlefield of the mid-1980's will be characterized by a combat intensity never before seen. As expressed graphically by MCTSSA (1977):

> *"The proliferation of sophisticated weapons and equipment among the great powers as well as their client states will blur any distinction between low and mid-intensity conflicts. The introduction of precision and guided munitions will give the individual infantryman the destructive powers formerly possessed only by crew-served weapons. In addition, speed of maneuver will be greatly enhanced by use of armored/motorized/mechanized forces. Adding to the confusion inherent in such an environment will be the voluminous amounts of data provided by complex information collection, processing, and reporting systems".*

The performance of tactical commanders in such an environment is highly dependent on their decision making behavior, in terms of their ability

to generate, evaluate, and select among alternative courses of action -- for example, to allocate weapon assets, countermeasures, etc., while considering the specific situational constraints and payoffs. Decision making behavior is, in turn, largely dependent on the commander's ability to manage the ever-increasing information load under conditions of severe time constraints and environmental uncertainty.

> *"The commander's information requirements on this modern, fast-moving, lethal battlefield will greatly increase. Current methods are insufficient in providing him with timely, accurate, and complete information in a usable form. The time compression factor will be such that the commander will need the fastest possible presentation of required information to allow the maximum time for decision making; the highlighting of critical items presented in an easily understood and useful format; and the suppression of extraneous items".*

Computer support of the information management and decision making function appears to be the most promising path to performance improvement.

> *"Automation is being introduced into virtually every functional area of command and control: fire support, air control, intelligence, logistics, and manpower. In the 1980 time frame the unprecedented volume of information from these systems that is pertinent to tactical decisions cannot be received and processed at operation centers without the aid of automation".*

An issue of particular concern is computer support of small units, i.e., at the battalion and company levels. Currently, these levels of command do not have any organized automated support for information management or decision aiding. Since battalion and companies furnish major inputs to high-level C3 systems, any errors and delays on their part may lead to significant reduction of overall command effectiveness. Thus, the small unit commander is both in need of help and pivotally important to overall system performance. Accordingly, techniques for alleviating some of this problems have a high payoff potential. In this program, the focus is on the Marine battalion commander.

1.2.2 Automated Information Management. The goal of the proposed 12-month program is to apply Perceptronics' AIS methodology to the Marine TCO system as represented on the MTACCS Interim Test Facility. The AIS will aid TCO operations by managing transfer of critical information among front-line sources, tactical data bases, and system users. In brief, the AIS functions by characterizing messages along a measurable set of attributes. The attributes comprise such factors as message content, area, age, accuracy, and geographic locale. The information selection policies of different users are then modeled for each tactical situation as distinct vectors of attribute weights. The set of multi-attribute models inherent in the AIS serve the following functions:

(1) Automatically routing messages from sources to various users.

(2) Automatically reprioritizing the queue of messages as command situations change.

(3) Scanning the data base for critical situation relevant data.

Attribute weights are estimated adaptively from observed user behavior. This methodology is discussed in detail in Chapter 2.

2. TECHNICAL BACKGROUND

2.1 Overview

Automated information management in support of C3 functions of small Marine units focuses on individualized evaluation and distribution of information. Multi-attribute models are used to take into account data characteristics, operator responsibilities, and situational demands. This chapter describes the tactical decision making environment, discusses a methodology for automated information management, and presents plans for experimental validation of the decision aids.

2.2 The TCO System and its Environment

The Marine Tactical Combat Operations (TCO) system is one of eight functionally oriented tactical and training systems included in the Marine Tactical Command and Control Systems (MTACCS) concept slated for operation in 1985. The other seven are:

(1) Marine Integrated Fire and Air Support System (MIFASS).

(2) Marine Air Command and Control System - 1985 (MACCS-85).

(3) Marine Air-Ground Intelligence System (MAGIS).

(4) Position Location Reporting System (PLRS).

(5) Marine Integrated Personnel System (MIPS).

(6) Marine Integrated Logistics System (MILOGS).

(7) Tactical Warfare Simulation Evaluation and Analysis System (TWSEAS).

The TCO System supports commanders and their staff in carrying out functions in the areas of operations and intelligence, including planning, intelligence production, and the monitoring and directing of tactical operations. The system provides this support to ground elements, air elements, and Marine Air-Ground Task Force (MAGTF) Headquarters.

TCO functions can be grouped into five top-level functional areas:

(1) Operational Support
(2) Intelligence Support
(3) Fire and Air Support
(4) Logistics Support
(5) Personnel Support

MTACCS Interim Test Facility. Alternative approaches to the automation of MTACC systems will be tested on the minicomputer-hosted MTACCS Interim Test Facility. The MTACCS Interim Test Facility will provide for:

(1) The capability to support the evaluations of automation concepts for the TCO and other MTACC systems.

(2) The representation of the tactical environment in which the MTACC systems are expected to function.

(3) Control of this representation by means of graphic and alphanumeric terminals manned by Marine Corps personnel acting in an interactive man-machine mode.

The MTACCS Interim Test Facility can be considered an operationally-oriented laboratory where requirements are defined, tested,

refined, and analyzed before they are implemented on the battlefield. As such, it should be an ideal test facility for evaluation of proposed decision support systems. The software functions performed on the MTACCS Interim Test Facility are included in Figure 2-1.

The exercises performed will consist of activities supported by a sequence of events and data inputs that emulate an actual military operation. The scenario for the coming year is based on an infantry battalion as part of a large force, i.e., Marine Amphibious Force (MAF) making an amphibious landing across the beach at Camp Pendleton. This constitutes the friendly side of the scenario. The Interim Test Facility will not have any simulated air support. Consequently, the scenario picks up with operations ashore. The aggressor or enemy force will be a mythical force tailored after likely adversaries. All information pertaining to the aggressor will be obtained from the Army aggressor's handbook. The basis for definition of friendly forces will be the Landing Force Operational System Study (LFOSS). The LFOSS is a document that provides a description of friendly forces in the future (e.g. an estimate of friendly forces fifteen years in advance can be obtained from LFOSS).

2.3 Automated Information Management

2.3.1 General. To meet the requirements of modern computerized C3 systems, Perceptronics has developed and demonstrated an on-line Adaptive Model for automatically selecting information. The model is an extension of on-going information management programs developed for C3 systems (Samet, et al, 1977), and for advanced aircraft operations (Steeb, Chen, and Freedy, 1977). The model conceptualizes messages or data items as multi-dimensional entities which can be characterized by a set of measurable attributes. The model computes an aggregate multi-attribute evaluation (MAE) of the message as a selection criterion. The model will be used to aid in the transfer of tactical information among sources, database, and users.

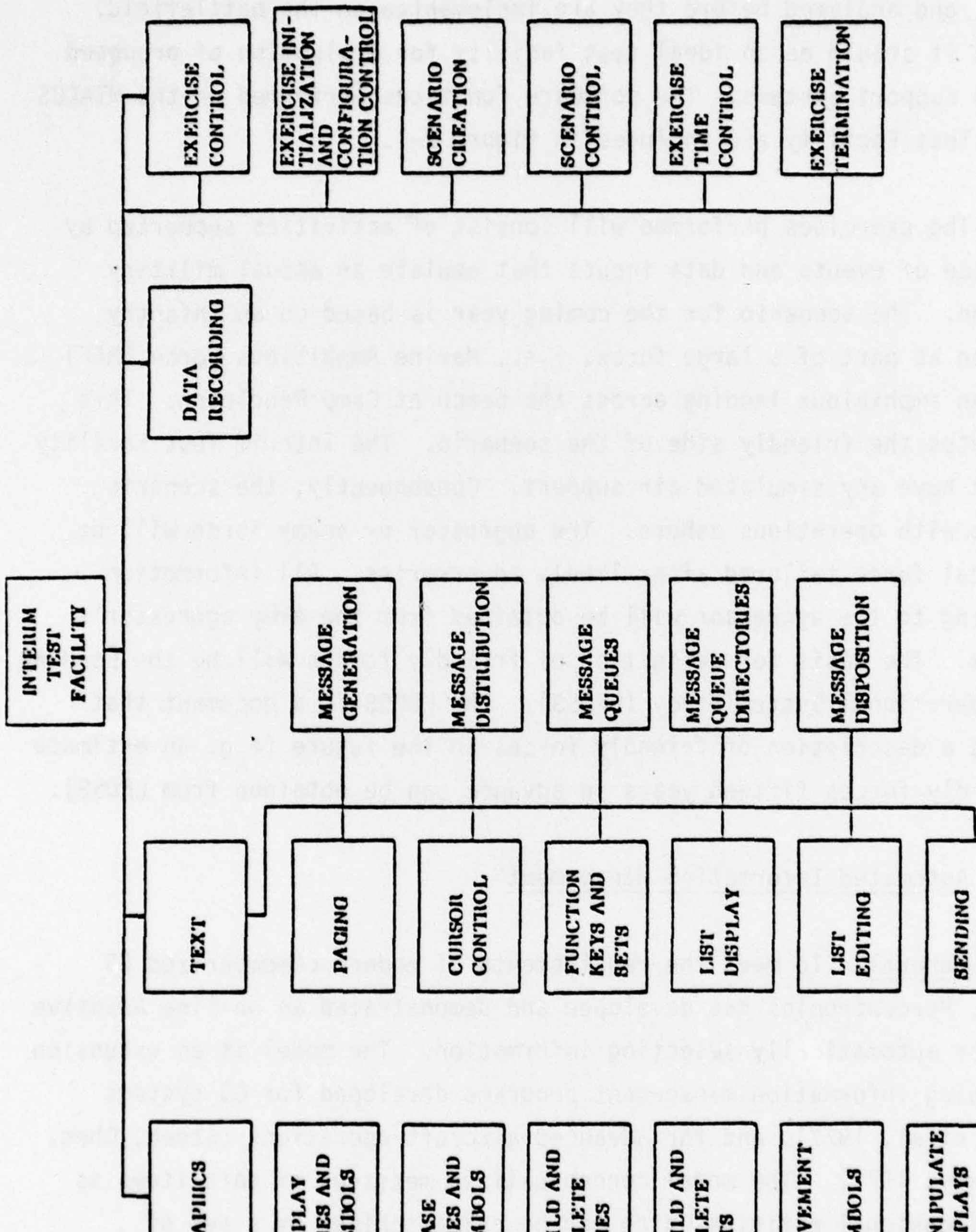

FIGURE 2-1
TEST FACILITY FUNCTIONS

2.3.2 System Organization. Figure 2-2 shows the major components of the selection system in block diagram form. Three stages are present: (1) determination of the additive attribute levels for each message; (2) rescaling of the levels using multiplicative factors; and (3) weighting and aggregation of the constituent attributes according to the specific user and command situation. Each of these functions will be treated in turn.

2.3.3 Attribute Definition. The additive attributes are those factors which act in a trade-off fashion (an increase in one factor will compensate for a loss in a second factor) and discriminate between user policies. As shown in Figure 2-2, the attributes are derived from the message headers and from the database. The attributes and their derivation follow:

Attributes A_1 to A_5: content area. Each message is categorized in the header according to content area. Approximately 100 numbered descriptors or data unit identifiers (DUIs) are currently used for this categorization. Table 2-1 shows a subset of this list. By analysis, the set of DUIs can be partitioned into a set of 4 - 6 meaningfully distinct content areas for each user. These membership areas define the content attributes. Presence of a DUI in a given content area results in a unit level for that attribute, a zero level otherwise.

Attribute A_6: message age. The message header lists the time of origination of the message. The age is derived using the system clock.

Attribute A_7: message length. The number of bytes of text is obtained indirectly from the header.

Attribute A_8: user familiarity. The number of times the user has seen the message. This is maintained in an internal table.

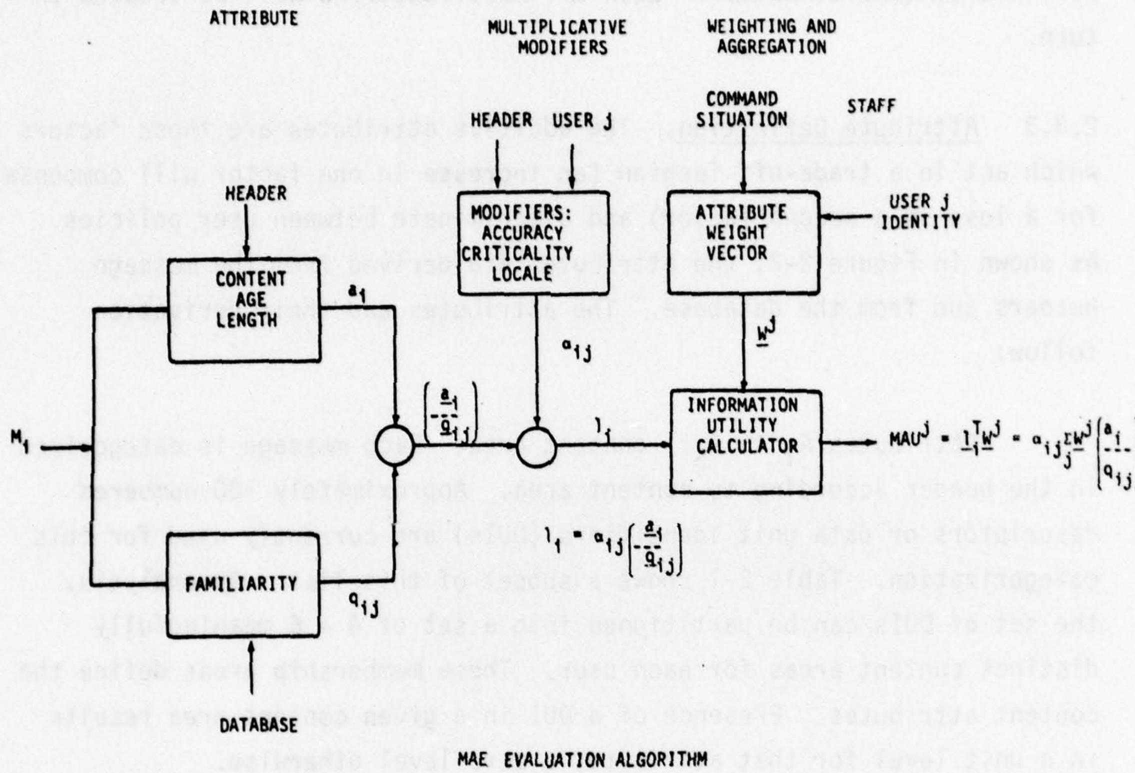

FIGURE 2-2
MAE EVALUATION ALGORITHM

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TABLE 2-1

REPRESENTATIVE DATA UNIT IDENTIFIERS

(1) World Area

(2) Program Indicator

(3) Installation Identification Serial Number

(4) Basic Encyclopedia Number

(5) Target System

(6) Target Identification

(7) Target List Part

(8) ABCA Target Identity

(9) Theater Target Number

(10) Document Source

The multiplicative factors are simply overall coefficients that raise or lower the evaluation of a message. The multiplicative form is required since a zero on the factor level results in a zero overall evaluation. No additional estimation is required, since each factor influence is assumed invariant with respect to user responsibilities and command situation. The factors and their origin follow:

Factor K_1: priority. Occasionally a high priority tag is assigned to a message. Presence of such a tag results in multiplication of message importance ($K_1 > 1$). A K_1 of unity results otherwise.

Factor K_2: accuracy/credibility. An accuracy estimate is provided when unreliable information sources are used. $0 < K_2 < 1.0$ provides a suitable range.

Factor K_3: geographic relevance. The geographic location associated with a message is encrypted in a 5 - 7 digit code on the header. This can be matched with a coded listing of the primary geographic responsibility of the user. Matches between header and user listing result in a unity value for K_3, while non-matches result in a degradation of importance; $0 < K_3 < 1$.

The above set of additive attributes and multiplicative factors is considered to make up a feasible set. All of the factors are directly accessible from the message headers and the database. The set appears suitable for implementation although additional factors may be easily added if required.

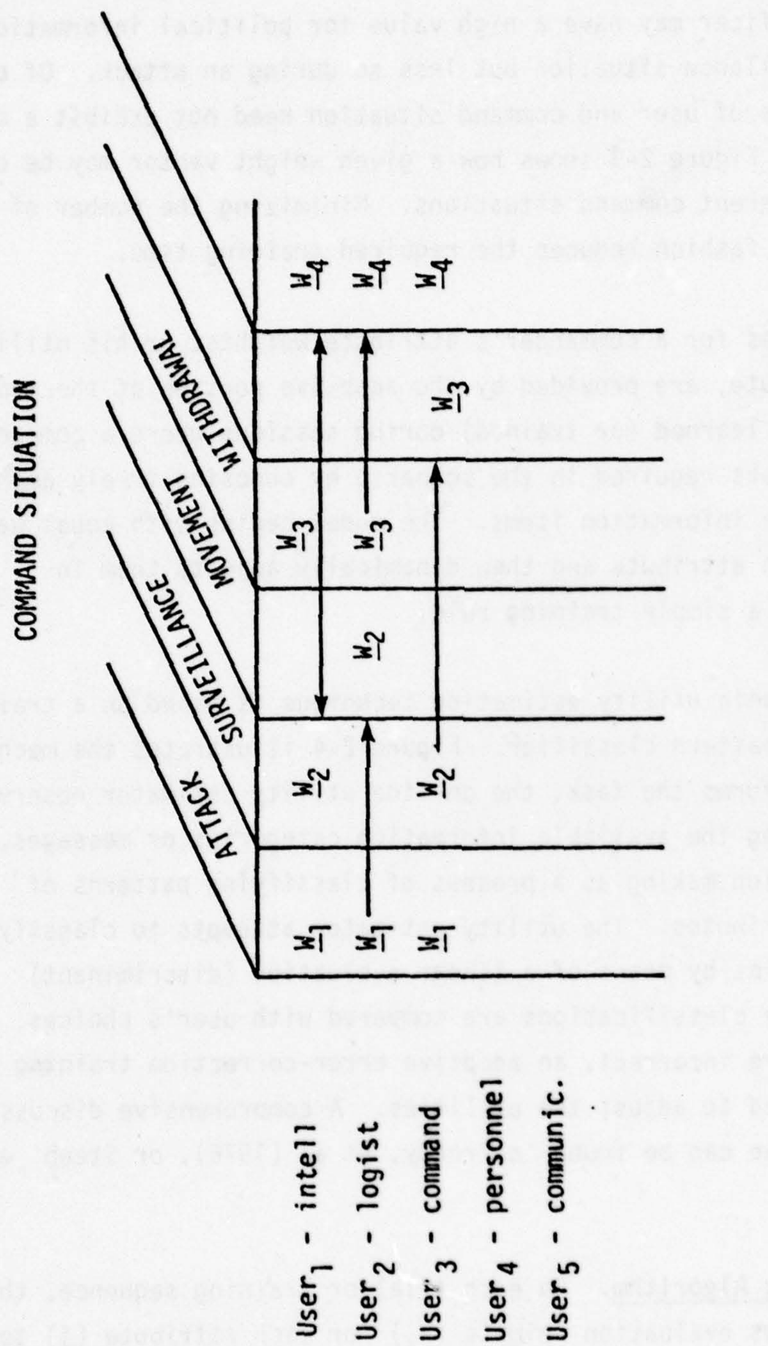
2.3.4 <u>Attribute Weight Vector</u>. Each user is assumed to have a policy of information selection that depends on his responsibilities and on the current command situation. This policy is reflected in a separate vector of attribute weights for each distinct situation. For example, an

intelligence officer may have a high value for political information during a surveillance situation but less so during an attack. Of course, all combinations of user and command situation need not exhibit a distinct weight vector. Figure 2-3 shows how a given weight vector may be common to several different command situations. Minimizing the number of weight vectors in this fashion reduces the required training time.

Estimates for a commander's attribute weights, or his utility for that attribute, are provided by the adaptive portion of the model. The weights are learned (or trained) during sessions where a commander performs the tasks required in the scenario by choosing freely among a menu of possible information items. The model begins with equal weights assigned to each attribute and then dynamically adjusts them in accordance with a simple training rule.

The dynamic utility estimation technique is based on a trainable, multi-category pattern classifier. Figure 2-4 illustrates the mechanism. As the user performs the task, the on-line utility estimator observes his choices among the available information categories or messages, and views his decision making as a process of classifying patterns of information attributes. The utility estimator attempts to classify the attribute patterns by means of a linear evaluation (discriminant) function. These classifications are compared with user's choices. Whenever they are incorrect, an adaptive error-correction training algorithm is used to adjust the utilities. A comprehensive discussion of this technique can be found in Freedy, et al (1976), or Steeb, et al, (1977).

Training Algorithm. On each trial or training sequence, the model uses the previous evaluation weights (W_j) for each attribute (j) to compute the multi-attribute evaluations (MAE_i) for each available information category (i).



USER WEIGHTING KEYED TO COMMAND SITUATION

FIGURE 2-3

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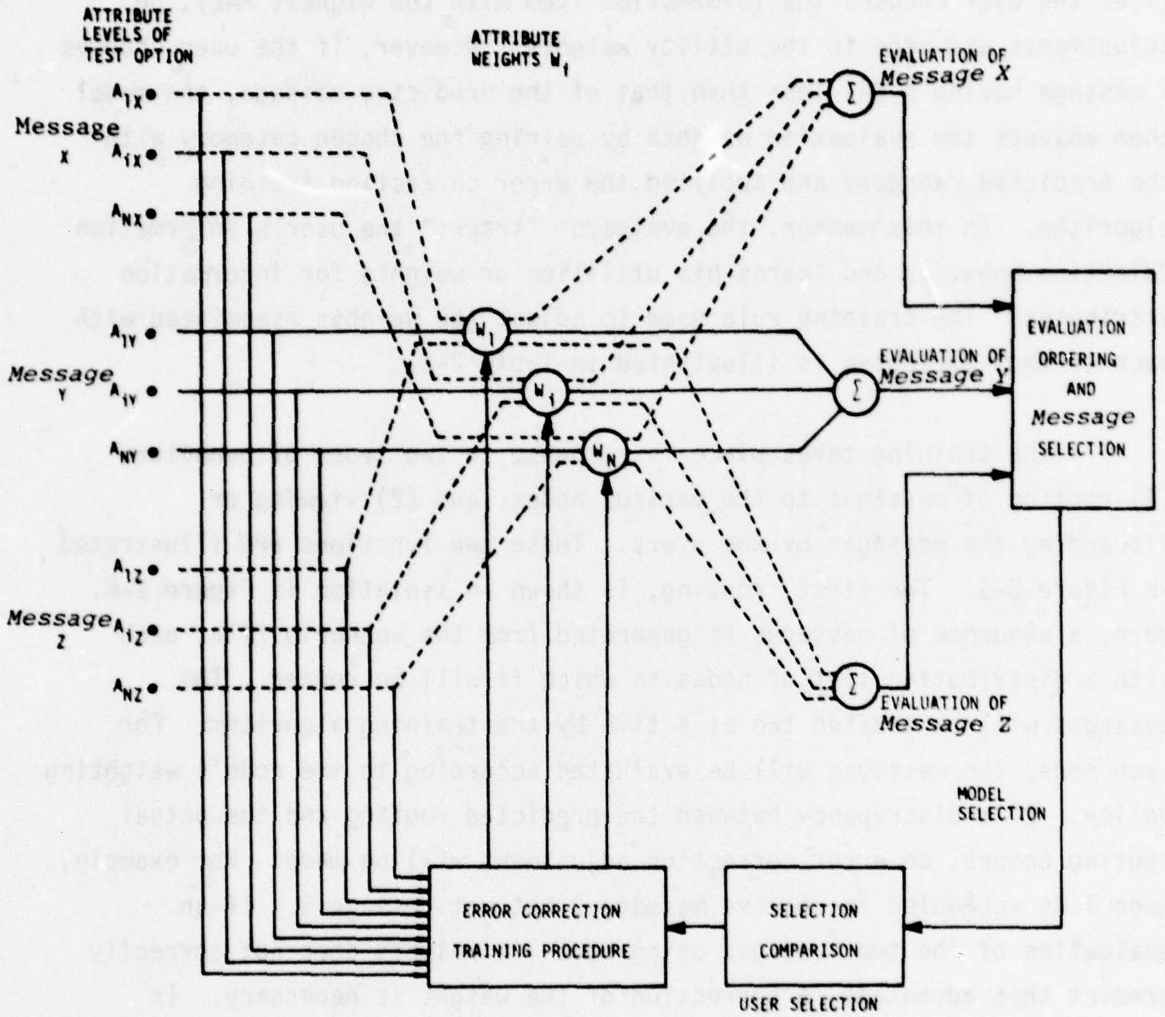

FIGURE 2-4
SCHEMATIC REPRESENTATION OF
ADAPTIVE EVALUATION ESTIMATOR

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$$MAE_i = \sum_{j=1} W_j A_{ji}$$

The model predicts that the user must always prefer the available information item with the maximum MAE value. If the prediction is correct (i.e. the user chooses the information item with the highest MAE), no adjustments are made to the utility weights. However, if the user chooses a message having a MAE less than that of the predicted message, the model then adjusts the evaluation weights by pairing the chosen category with the predicted category and applying the error correction training algorithm. In this manner, the evaluator "tracks" the user's information selection behavior and learns his utilities or weights for information attributes. The training rule used to adjust the weights associated with each of the attributes is illustrated in Table 2-2.

The training takes place in response to two types of behavior: (1) routing of messages to the various nodes, and (2) viewing or discarding the messages by the users. These two functions are illustrated in Figure 2-5. The first, routing, is shown in isolation in Figure 2-6. Here, a sequence of messages is generated from the scenario file, each with a distribution list of nodes to which it will be routed. The messages will be treated two at a time by the training algorithm. For each node, the messages will be evaluated according to the node's weighting policy. If a discrepancy between the predicted routing and the actual routing occurs, an error correcting adjustment will be made. For example, node 1 is scheduled to receive message 2 but not message 3. If an evaluation of the two messages using node 1's weights does not correctly predict this advantage, a correction of the weight is necessary. In abbreviated form, the adjustment is as follows:

$$[W_{11}, W_{12}, \ldots W_{1N}]^{\text{new}} = [W_{11}, W_{12}, \ldots W_{1N}]^{\text{previous}}$$

$$-\lambda \left\{ [A_{21}, A_{22}, \ldots A_{2N}] - [A_{31}, A_{32}, \ldots A_{3N}] \right\}$$

TABLE 2-2

WEIGHT-TRAINING RULE

						CORRECTION DIFFERENCE		
Adjusted Weight		Previous Weight		Adjustment Factor*		Chosen Information-Source Attribute Level		Predicted Information-Source Attribute Level
$\hat{W}_1$	=	W_1	+	λ	$\cdot$	$(A_{1c}$	-	$A_{1p})$
.		.		.		.		.
.		.		.		.		.
.		.		.		.		.
$\hat{W}_j$	=	W_j	+	λ	$\cdot$	$(A_{jc}$	-	$A_{jp})$
.		.		.		.		.
.		.		.		.		.
.		.		.		.		.
$\hat{W}_N$	=	W_N	+	λ	$\cdot$	$(A_{Nc}$	-	$A_{Np})$

* λ is a constant which influences the rate of training.

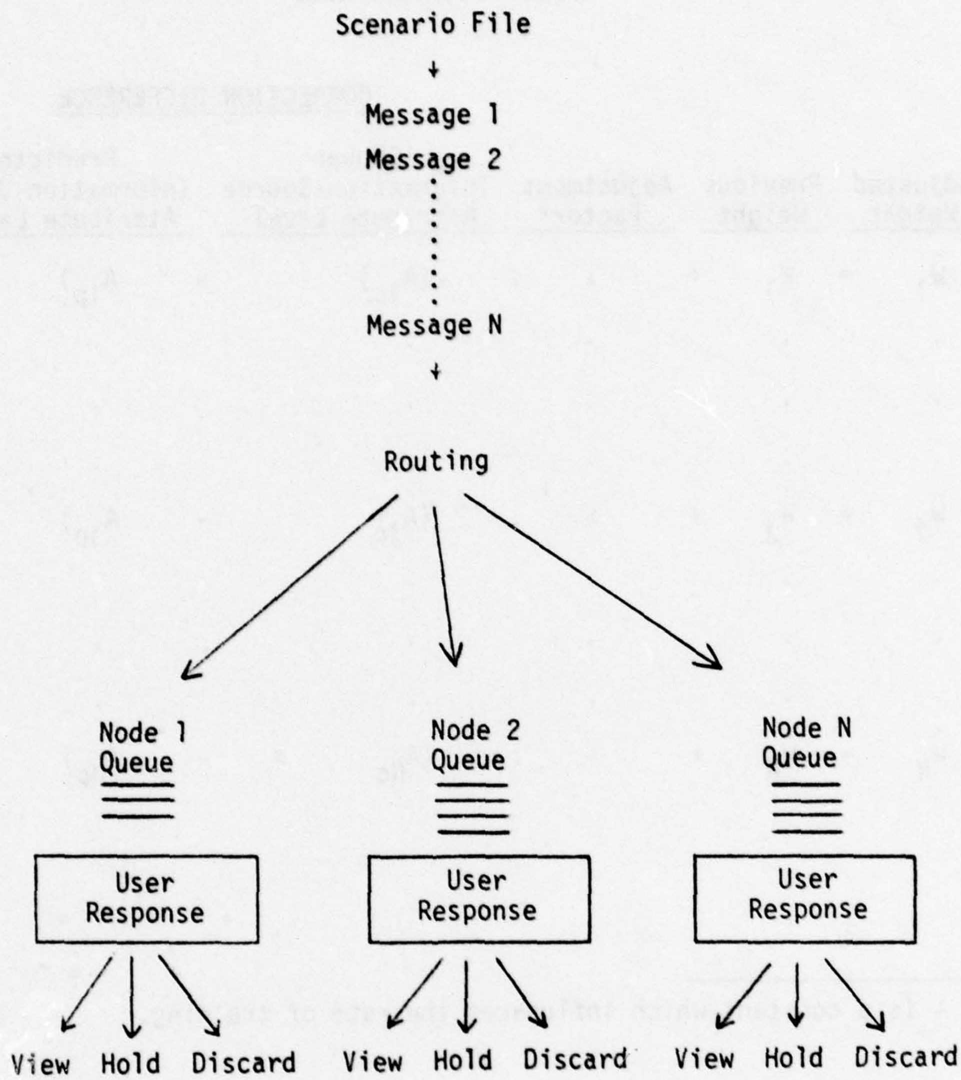

FIGURE 2-5
MESSAGE HANDLING BEHAVIORS
IN INTERIM TEST FACILITY

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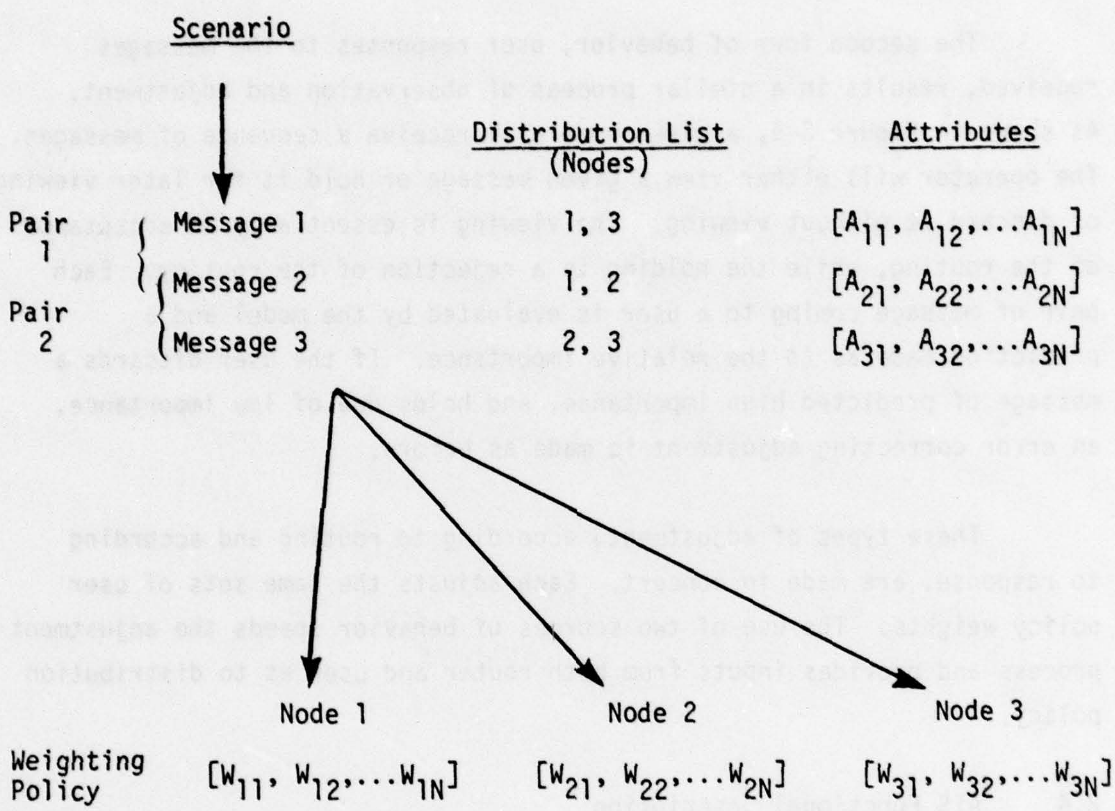

FIGURE 2-6
ROUTING BEHAVIOR

Continuing in the example, node 2 is sent message 2 but not message 1, and node 3 is sent message 3 but not message 2. Adjustments are made to the node 2 and 3 weight vectors if the predictions are incorrect. In this way, model predictions for each node are evaluated for each pair of messages, and systematic corrections are made for errors.

The second form of behavior, user responses to the messages received, results in a similar process of observation and adjustment. As shown in Figure 2-5, a given node will receive a sequence of messages. The operator will either view a given message or hold it for later viewing or discard it without viewing. The viewing is essentially an acceptance of the routing, while the holding is a rejection of the routing. Each pair of message coming to a user is evaluated by the model and a prediction made as to the relative importance. If the user discards a message of predicted high importance, and holds one of low importance, an error correcting adjustment is made as before.

These types of adjustment, according to routing and according to response, are made in concert. Each adjusts the same sets of user policy weights. The use of two sources of behavior speeds the adjustment process and provides inputs from both router and user as to distribution policy.

2.4 AIS Functional Description

The AIS serves the following functions:

(2) It automatically routes messages from front line sources to various nodes within the system.

(2) It automatically prioritizes the message queue for each user as command situations change.

(3) It scans the database for critical situation specific messages.

Figure 2-7 illustrates the AIS aiding of the TCO information dissemination function during the conduct of an exercise on the MTACCS Interim Test Facility.

During a typical TCO exercise on the MTACCS Interim Test Facility, the computer system serves the exercise players at tactical positions and members of the Control and Simulation Team (CST) at control positions. The data processing system supports the entry and transmission of messages originating from both the pre-established simulation file and the live operator positions. Exercise operators assigned to each tactical position perform their normal military functions. They respond to stimuli from other operators, from CST members and from outputs of the simulation file. The system contains routing tables to control the distribution of messages. The routing tables are based on message type and originating node. They provide the preliminary distribution list for each message. The operators can add one recipient to the message distribution list without having to change the standard routing table. They possess temporary manual override capability on the standard routing table by designating a specific destination for a message at the time the message is sent. Further, for each user, separate message queues exist for each message precedence category.

The Adaptive Information Selection will aid the projected TCO routing channel (in the performance of these exercises on the test facility) by automatically routing the messages and prioritizing the messages in each user's queue by utilizing the multi-attribute evaluation model approach. The specific functions of the various elements of the AIS as shown in Figure 2-7 are discussed below.

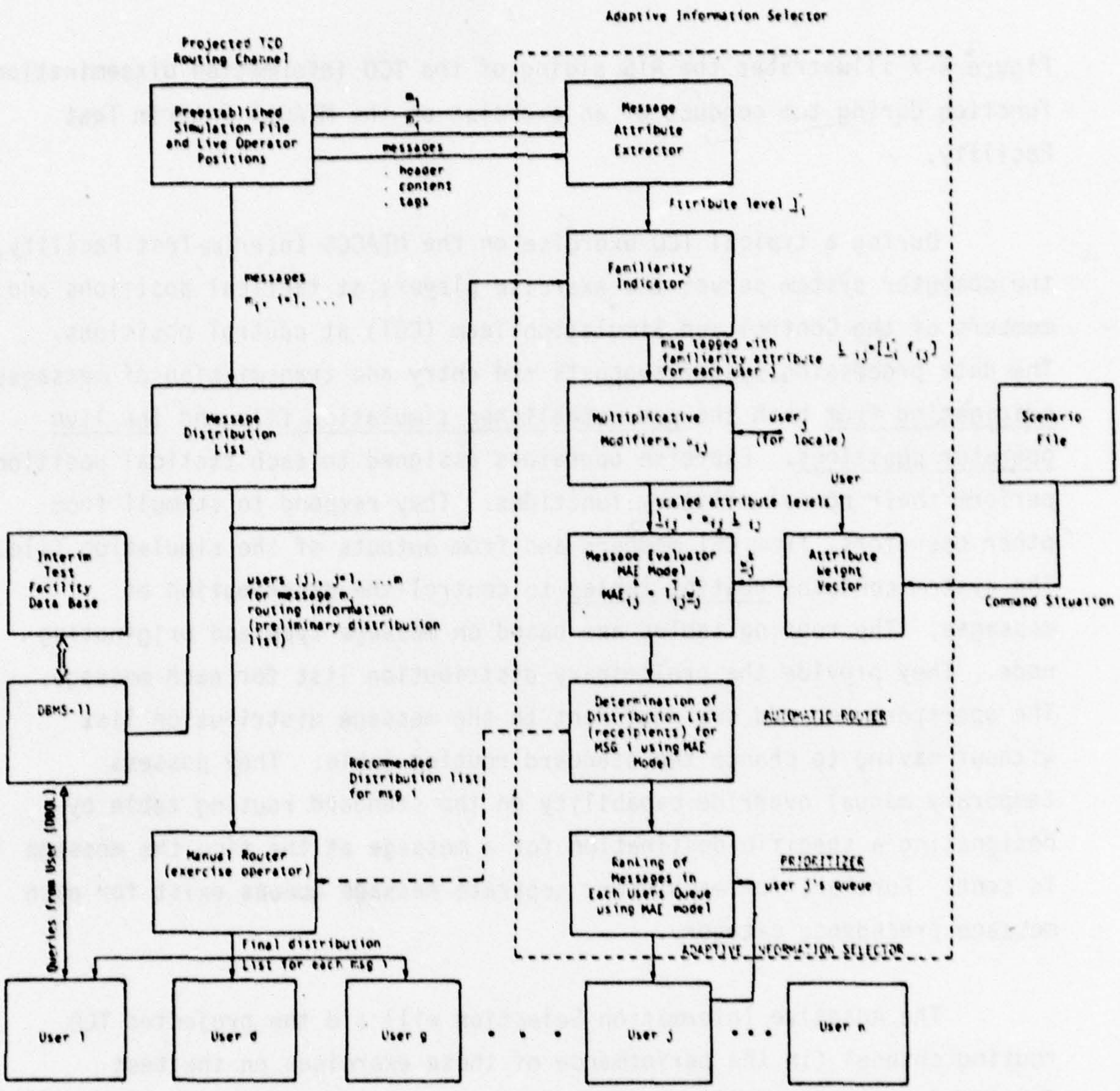

FIGURE 2-7
ADAPTIVE AIS AIDING OF SIMULATED TCO
FUNCTIONS ON MTACCS INTERIM TEST FACILITY

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(1) Message Attribute Extractor. The message attribute extractor "extracts" the attribute levels from each message (supplied by the pre-established simulation file and line operator positions) based on its header, content area, and tags. This information is partly contained in a table look-up format for each message ID.

(2) Familiarity Indicator. This is a counter for determining the number of times specific users have viewed a particular message. It assigns a value to the familiarity attribute level based on this count.

(3) Multiplicative Modifiers (MM). Based on message headers resident in the TCO database, the MM function outputs scale factors to rescale the attribute levels before sending the message to the MESSAGE EVALUATOR. Two of the MM, viz accuracy and criticability are user independent, whereas geographic location or locale is a function of the specific user.

(4) Message Evaluator (ME). The ME function weights and aggregates the constituent attributes according to each specific user and command situation. Using a set of multi-attribute evaluation (MAE) models, it performs the following two functions:

(a) It determines (1) distribution list of recipients (user 1, d, g in Figure 2-7) for each message which it recommends to the exercise operator (manual router). The exercise operator retains the prerogative to accept or reject this recommendation. (2) it prioritizes or ranks the messages in each user's queue according to

changes in the command situation as reflected by corresponding values in the weight vector provided by the WEIGHT VECTOR UPDATE FUNCTION.

(5) <u>Weight Vector Update (WVU)</u>. The WVU function selects appropriate weights per attribute for each user as the command situation changes.

3. EXPERIMENTAL STUDIES

3.1 Automated Simulators

It is planned to subject the AIS to two stages of exploratory testing in the current year's work. The first stage will entail automated simulations without human subjects. Sets of attribute vectors will be generated and presented to a "model operator". The model operator will be programmed to make decisions according to a set of pre-set weights. Refinements of the adjustment rules, training procedures, situation structuring, and model form can be made quickly and easily using this type of automated simulation.

3.2 Operational Simulation

Software is currently being written to use the Tactical and Negotiations Game (TNG) as a preliminary "gauge-test" of the capabilities of the AIS. The TNG is an in-house simulation of a tactical message distribution situation. The intent of this exercise is to demonstrate the effectiveness of the AIS in comparison with an operational Adaptive Aiding System (a precursor to the AIS).

The software of the Tactical and Negotiations Game (TNG) was carefully reviewed. It was determined that its structure is somewhat incompatible with the type of C3 messages and environment existent on the Interim MTACCS Test Facility. The messages do not contain the pertinent header information necessary for proper discrimination in the Multi-Attribute-Evaluator (MAE) model. Timing information and distribution information are similarly not available concerning the TNG messages. These messages are currently being modified to incorporate this necessary information.

The in-house operational simulation currently being implemented will consist of two phases. The first phase concerns the training subsystem. Here, the parameters (user weights) for the MAE model are determined during a training session. These weights will be specific to the subject and the command situation. The system will display a pair of randomly selected messages from the entire message pool on the screen. The subject will indicate his preference for one of the two messages depending on his information preference and the current command situation. After a sufficient number of trials for each command situation, the subject's weights will converge to a stable set. At least two subjects will be trained before going on to the next phase. A logical description of the Master Scheduler for the training subsystem is presented in Table 3-1.

The second phase of the operational simulation concerns the testing subsystem. During this phase, the testing will take place to determine if the system trained weights conform to actual informational preferences. The system will continually route messages to at least two different subjects. The messages will eventually form a queue at each subject's terminal.

The system will then select a message from the visible queue to present to the subject. The subject can rate whether the message selected from the queue for him was the one he would have preferred under the given command situation. In this manner during the testing phase, the system can gather statistics on how well the MAE model was trained to automate the routing and prioritizing function for a particular subject. A logical description of the Master Scheduler for the testing subsystem is presented in Table 3-2.

TABLE 3-1

PDL - DESCRIPTION OF TRAINING SUBSYSTEM

Master Scheduler

```
getatt      Read all attributes
            Initialize weight matrix

crtset      Initialize subject CRT
            For (COMMAND_SITUATION=1,N)
                 CONVERGE='FALSE'
                 While not(CONVERGE)

slect2               Select attribute-vector pair
                     Display attributes
                     Process subject response

trnmau               Conditionally train current weights
                     If (training occurred)

normliz                  Normalize weight
                     Update training statistics
                     If (criteria met)
                         CONVERGE='TRUE'

             Write weight matrix on a file
             End
```

TABLE 3-2

PDL - DESCRIPTION OF TESTING SUBSYSTEM

Master Scheduler

```
getbias        Calculate message byte-biases

getatt         Read all attributes
               Read weight matrices

crtset         Initialize both CRTs
               Reset clock and statistics
               Get scenario from operator
               (including optional control cases)
               For (CONTROL_CASE=1, MAX)
                   COMMAND_SITUATION=FIRST
                   IF (COMMAND_SITUATION≤LAST
                      Sleep N seconds
                      Increment clock by N
                      If (Time for next message)
                          Randomly select a message
route                     Route it

subjmon              Monitor subject1
subjmon              Monitor subject2
                     If (Time to change)
                         Get next command situation

                     Print average rating

               End
```

3.3 Transfer of AIS

It was agreed that the best approach for implementing the AIS at the Interim MTACCS Test Facility would be to recode the modules of the AIS in Fortran at the Test Facility itself. The inhouse simulation is being coded in the C language under the UNIX operating system. The Test Facility uses a PDP 11/70 computer running uder the IAS operating system. Perceptronics has a PDP 11/45 running under UNIX and does not possess the Data Base Management System (DBMS-11) used at the Interim MTACCS Test Facility. Without DBMS-11, no attempt can be made to implement the entire AIS in-house. The effort will therefore be directed towards checking out the individual modules of the AIS at Perceptronics and then transferring them to the Interim MTACCS Test Facility. The major effort involved in implementing the AIS will be in interfacing with the existing software of the test facility. This interfacing is best accomplished at the Interim MTACCS Test Facility itself. We have received confirmation from personnel at Camp Pendleton that this is the best approach. In this way, the program effort can concentrate directly on the Marine application.

3.3.1 Equipment. The MTACCS Interim Test Facility system comprising a minicomputer network will eventually consist of:

1 DEC PDP-11/70 minicomputer
8 DEC VT-52s (terminals)
2 Vector General graphic devices (CRTs)

Software. The software for the new MTACCS Interim Test Facility system will consist of:

(1) A CODASYL-type database management system (DEC DBMS-11 Version 2).

(2) A powerful and flexible operating system that provides real-time, periodic time-sharing and batch operations (IAS Version II).

(3) Available languages include COBOL, FORTRAN, MACRO, CORAL-66.

3.3.2 TCO Database Structure. The TCO database will be a distributed database containing the aggregate of the data stored at all TCO centers. The distributed aspect will be transparent to the user. Applications programs making up our AIS model will access the database and so will users through the Database Query Language. Our portion of the database will consist of the tables for routing and the data structures for the weight vector information.

The Data Base Management System greatly facilitates the organization and management of information used at the Interim MTACCS Test Facility. It relieves the applications programmer, writing software such as the AIS, from the burden of having to know the physical structure of the data base. The programmer would normally have to use the capabilities of the operating system to perform all his input and output. This involves knowing all the possible access methods, the proper syntax for using these access methods and, in general, very bothersome details. With the Data Base Management System, the user need have only an application-oriented or logical view of the data base and not worry about how it is physically stored.

The Data Base Management System being used by the Interim MTACCS Test Facility is Digital Equipment Corporation's DBMS-11 used on a PDP 11/70. DBMS-11 is an implementation of the CODASYL data base language specifications. It provides data base facilities for both PDP-11 COBOL programs and programs written in other languages. The DBMS-11 Data Base

Control System provides data control and manipulation functions that application programs use to manipulate data stored in the data base. A COBOL program invokes these functions through the COBOL Data Manipulation Language (DML) statements. A non-COBOL program must access these functions via an external subroutine CALL statement. The generic interface program which manipulates the data base will be written in COBOL. This program interfaces between the AIS which is written in FORTRAN and DBMS-11.

DBMS-11 supports both network and hierarchical types of data structures which are used on the Interim MTACCS Test Facility. These data structures are defined using a language facility which is part of DBMS-11. DBMS-11 provides separate language facilities for the description of data and for the manipulation of data. This separation removes the data description function from the scope of application programs. Also, the separation of data description facilities allows integration of all data and data relations into a data base that is common to all application programs that use it. This reduces data redundancy and improves data consistency. The data description features of DBMS-11 provide for the description of the complete data base and for descriptions of portions of the data base. The description of the complete data base is referred to as the schema, while the descriptions of portions of a data base are called subschemas. While there is only one schema for a database, there may be any number of subschemas, each describing a portion of the data base used by one or more applications programs such as the AIS.

A subschema allows an application program to have access to only the particular part of the data base that concerns it. The Data Base Administrator (DBA) creates the schema and subschemas using DBMS-11's data description languages (DDLs).

The following are important concepts about schemas and subschemas:

(a) The schema is established independently of any user program or any subschema.

(b) A subschema is a consistent and logical subset of the schema from which it is drawn.

(c) Any number of subschemas can be treated and are independent of each other.

(d) A user program invokes a subschema and can reference only those data base records defined in the subschema.

Perhaps the most important feature of a data base management system is the ability to support logical data relationships. It is this capability to relate record occurrences to one another that reduces duplication of stored data and provides direct access to associated records. The set is the mechanism by which a logical relationship is established between two or more record types. It is a concept that permits the construction of a variety of data relationships. Each occurrence of a set includes one occurrence of an owner record type and zero or more occurrences of one or more member record types. Any record occurrence can participate in any number of set relationships as either an owner or member. This feature allows the construction of complex integrated data structures.

A diagram of a portion of the schema definition for the Interim MTACCS Test Facility is shown in Figure 3-1. Each box represents a record type and the directed arrows define a set relationship. The tail of the arrow touches the owner record type and the point of the arrow touches the member record type. The labels and acronyms on the arrows name the set relationships and provide information on how the records are ordered within the set. They also provide information on whether or not new records of a particular type are automatically or manually included within the set.

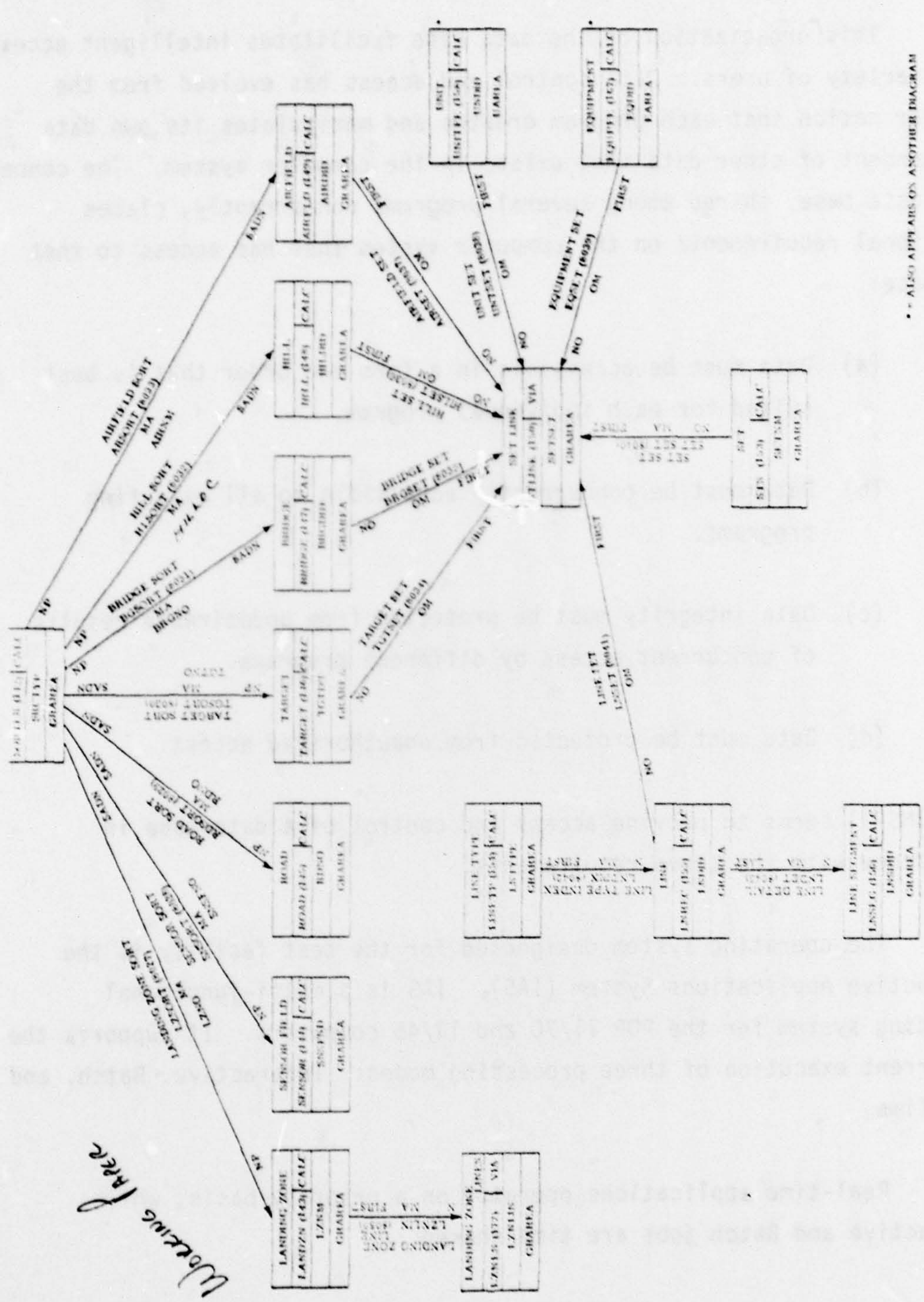

FIGURE 3-1
SCHEMA DEFINITION FOR THE DATA BASE
OF THE MTACCS INTERIM TEST FACILITY

This organization of the data base facilitates intelligent access by a variety of users. Data control and access has evolved from the earlier notion that each program creates and manipulates its own data independent of other data that exists in the computer system. The concept of a data base, shared among several programs concurrently, places additional requirements on the computer system that has access to that database:

(a) Data must be accessible in a form and order that is best suited for each individual program.

(b) Data must be concurrently accessible to all executing programs.

(c) Data integrity must be protected from undesirable results of concurrent access by different programs.

(d) Data must be protected from unauthorized access.

The DBMS-11 seems to provide access and control of a data base in accordance with the above requirements.

The operating system designated for the test facility is the Interactive Applications System (IAS). IAS is a multi-functional operating system for the PDP 11/70 and 11/45 computers. It supports the concurrent execution of three processing modes: Interactive, Batch, and Real-Time.

Real-time applications operator on a priority basis, while Interactive and Batch jobs are time-shared.

3.4 Estimated Burden of AIS

The following is a breakdown of the costs of operating the AIS. These costs involve the additional memory needed for the software and the added response time due to the AIS. In the memory forecast, (Table 3-3), total cost is reflected in the predicted number of lines of Fortran code needed to implement each principal function. The total number of lines is then translated into a memory estimate in bytes. This does not include I/O routines or other system functions which should already be in memory. In addition, the extra data areas needed are given, such as for the attribute level tags associated with each message.

For the response time calculations, a worst case example is given with the assumptions of a message pool of 105 messages with eight attributes each and three users receiving the messages. The Router and Familiarity Indicator programs should add minimally to the response time of the AIS because much of the code involved in these routines should already exist. Essentially, the only addition to response time is due to the Message Evaluator and Prioritizer. The calculations of execution time involved in these routines is shown in Table 3-4.

As of now, the worst case MCTSSA estimate for message delay on the TCO is 5 seconds (based on former test facility), and the amount of memory allocated for the test facility is 300K bytes. Our prediction of the AIS response time is about .05 seconds, which compared to the existing response time, is negligible. Also, the 24K bytes of memory needed for the AIS is small compared to the available storage. It appears that the impact on the system of the added response time and memory of the AIS will be minimal.

TABLE 3-3. MEMORY FORECAST

Principal Function	Lines of Fortran Code
Critical Message Scanner	150
Familiarity Indicator	100
Modifier	100
Weight Vector Updater	100
Message Evaluator	50
Prioritizer	100
Total Lines	600
Number of Bytes	20K
Data Areas	4K
TOTAL MEMORY	24K

TABLE 3-4. AIS RESPONSE TIME (WORST CASE)

SAMPLE 105 messages
8 attributes
3 users

MAU CALCULATIONS:

105 X 8 X 3 X (1.0μ sec. + 2.5μ sec.) Floating Pt. add & multiply

= 8.8m sec. + 10m sec. (overhead execution time)

= 18.8m sec.

To prioritize messages:

= 105^2 X 2.0μ sec. (for a compare & load)

= 22m sec. + 10m sec. (overhead execution time)

= 32m sec.

Total AIS response time = 51m sec.

4. REFERENCES

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